Title: Analysis of the Tidal Wave

Link to Outcomes:

● **Acquisition/ Integration**	Students will apply the concept of Conservation of Energy to predict the behavior of a roller coaster.
● **Interpretation/ Explanation**	Students will reflect on the forces involved in the roller coaster ride and comment on the safety of the design.
● **Thinking/ Acting**	Students will compare observations to the predictions of theory and appreciate the practical application of physics formulas.
● **Attitudes**	Students will understand the connections between physics and life experiences.
● **Methods/ Materials**	Students will utilize estimation techniques to acquire data in a difficult environment. Students will measure distance, time and angle.
● **Problem Solving/ Decision Making**	Students will consider the safety of thrill rides and decide whether they will ride them.

Brief Overview:

The application of physics principles to the real world is made clear when the subject is an exciting experience for the students. In this lesson, conservation of energy and circular motion formulas are used to quantify the experience of riding a roller coaster. The ideas contained here are intended to be used in a culminating experience involving a field trip to the amusement park, but they can also be used with "canned" data supplied by the teacher. The analysis here is for the "Tidal Wave" coaster at Trimper's Amusements in Ocean City, MD, but it can be modified easily for other rides in other parks.

Grade/Level:

Grades 9 - 12

Duration/Length:

Preparation for the lab experience takes 1-2 periods; the actual field trip takes ½-1 day.

Prerequisite Knowledge:

Students need to know conservation of energy (specifically GPE and KE) and centripetal force equations. This lesson has been used with physics classes of all levels and in summer camp with groups of mixed ages without any previous physics background (but with considerable math ability).

Objectives:

Students will (or Students will be able to):

- collect data and calculate the speed of a passing roller coaster train.
- calculate the height of a roller coaster train by using triangulation.
- calculate the predicted speed of a falling roller coaster train using conservation of energy.
- compare theoretical and experimental results and calculate percent error.
- Calculate the centripetal acceleration experienced by a coaster train at the top of a loop.
- describe the sensations during a ride.

Materials/Resources/Printed Materials:

Students will need:

- a sighting device for triangulation
- a stopwatch
- a tape measure or knowledge of the length of their stride
- a guide sheet

Development/Procedures:

- The day before the field trip, go over the guide sheet. Divide the class into working groups for the experiment. Note: not all students will want to ride the roller coaster; mix groups so that all include at least one rider, and never force a student to ride. Supply data (false of course) and run through the calculations with the students. If necessary, measure the students' strides so that they can measure distances by pacing them off. Check to see that each group has a stopwatch and supply one if necessary.

- At the park, circulate among the students and assist them with estimating distance and angle if necessary. Engage the students in discussions of the experience both before and after they ride.

Evaluation:

Upon returning home, collect the students' work. Have the students compare their results. Discuss variations in data collected and ask the students to speculate why the results varied.

Extension/Follow Up:

The day after the trip, talk with students about the experience. A lively discussion usually will result. Supply data about other coasters and have the students calculate the speeds and accelerations on those rides.

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Analyzing the Tidal Wave

I. Finding the speed at the end of the first drop:

Measure the length of the train ______________________________ m.

Time the train as it passes through the station __________________ s.

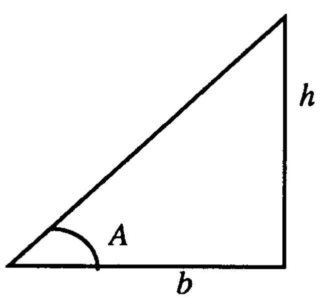
Calculate speed ($v = s/t$) ___________________________________ m/s

II. Does the actual speed match our prediction?

Converting GPE to KE gives the equation

$$V = \sqrt{2g\Delta h}$$

where $g = 9.8$ m/s^2. To determine Δh we use trigonometry:



Measure the baseline (b) ______________ m.
note: 1 ft. = 0.305 m

Sight the angle A to the center of the train _________ .

Calculate h (at the top of the lift) using $h = b \tan A$

$h =$ ______________ m.

Δh is this h minus the height of the train on the platform, so measure the height of the train on the platform (h_0):

$h_0 =$ ___________________ m then $\Delta h =$ __________________ m

So using the formula above, what is your predicted speed (V)?

V = _____________________________ m/s

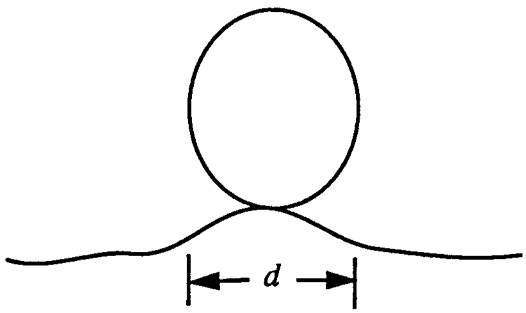
III. How close is the actual speed to our prediction? Calculate the percent difference (due to friction):

percent error =

$$\frac{|P - A|}{P} \times 100$$

percent error = _____________________________

IV. Calculate g forces in the loop.



From the sidewalk estimate d:

$d =$ ____________________ m.

So then calculate $r =$ ____________________ m.

Time the train over the top:

$t =$ ____________________ s.

and calculate v for the train over the top: v = ____________________ m/s

so then you can find centripetal acceleration from $a_c = v^2/r$

$a_c =$ ____________________ m/s^2

Repeat this calculation for the reverse trip.

V. Now ride the coaster and describe your sensations briefly below. Are you aware of the difference in g forces at the top and bottom of the loop? Where do you feel the greatest g force? Where the least? What do you feel during the drops? Enjoy!